Questions and related issues discussed at the "High-Resolution Modeling in the Northern Great Plains" workshop

Boulder, Colorado, September 24-25, 2015

Spatial Scale

What do we mean by high-resolution?

- It's a relative term.
- Recommend the use of absolute values to describe the scale i.e., 50km, 12km or 4km.

What would be an optimal resolution?

- That would depend on the study requirement and sensitivity of system being studied. Grid size has to be 4km or lower if one is interested in simulating convective precipitation by first principle (non-parameterized convection). On the other hand, propagating storm systems such as Meso-scale Convective Systems (MCS) are simulated at resolutions of ~20km.
- Trade offs: How much added value can a certain project afford?

What do impacts modelers need?

- 1km or higher resolution would represent the microclimate characteristics that typically affect ecological processes.
- Some High Resolution Climate Model (HRCM) products are available at ~4km, but for limited regions. Also, this resolution still needs to be validated.
- Most HRCM data is available at resolutions of >20km.
- Precipitation in Colorado Rocky Mountains better at 4km or higher resolution.
- Issues with ~1km HRCM output: we do not understand all of the physics of climate at that resolution; large stochastic component.

How important is the choice of parameterization (for snow and convective processes) relative to resolution?

- Choice of parameterization is considerable for both snow and convective processes.
- For convection, there is probably less variability with changes in resolution, until you get to the convection resolving scales (<4km). The latter is probably not true for snow, since the resolution plays such a strong role in terrain elevation.

Can we compromise between high temporal and high spatial resolution?

- We have climate data on high temporal but low spatial resolutions, yet decisions could typically require high spatial resolution information on coarser timescales.
- Although some impacts models and decisions only require an annual number, that number is often derived from higher temporal resolution data. We need the high temporal resolution to capture extremes, for example. The type of climate extreme

and the temporal resolution required to capture it will depend a lot on the application.

Some specific examples – climate *refugia*:

- Wolverine habitats depending on snowpack – can we accurately represent snow pockets in canyons throughout the seasons using a 36 km model?
- White pine recovery efforts – can we identify ideal microclimate conditions in climate change projections where efforts should be focused?

Is there an optimal resolution at which models appropriately simulate surface wind speed?

- This is region-specific; differences exist between mountains and plains

Convective Precipitation

What is important about organized convection in the Northern Plains?

- Relevant to the functioning of grassland, prairie potholes ecosystem, etc.
- Flooding and erosion.
- Daily cycle of the convective processes, as well as their frequency and intensity.

What advantages do HRCM offer?

- Better statistics of extreme rainfall
- Better for coupled processes, e.g., recycling of precipitation through evapotranspiration
- Coarser models typically do not get enough convective events, which could lead to drier soils and associated soil moisture feedbacks.

How do models represent the interaction between rainfall intensity and soil moisture?

- Rainfall dynamics will be incorrect if soil moisture feedbacks are not considered. GCMs, if anything, overdo the low intensity rain events, which tend to increase soil moisture, compared to high intensity events that likely just increase surface runoff.

What observational datasets do we use to validate models?

- Good observational gridded datasets to validate extreme precipitation and snowpack are lacking.
- Station data is also used to validate model output, but their spatial distribution is irregular and usually absent in the most critical places (e.g. in mountain regions or remote areas, where conservation efforts could be prioritized).

How important is the accurate simulation of snow processes?

- In the mountains, the primary concerns are snowpack and snowfall relative to rainfall.

- In the plains, phenology of snow cover is really important in determining ecological responses.

What temporal resolution is needed for different variables?

- Snow: For mechanistic modeling, daily snowfall is necessary. HRCMs can provide added value related to frost kill, late-season snowfall, etc. Here, HRCMs have a big advantage over statistical downscaling.
- Daily to sub-daily data is necessary for wind speed, as it significantly affects evapotranspiration and evaporative demand.

Land surface processes and feedbacks

For ecological impacts, what advantages does a better representation of land surface feedbacks offer?

- Highly non-linear ecological processes that are affected by land phenology and interactions with the atmosphere (e.g., soil moisture, phenology, evapotranspiration, precipitation from high intensity events) should be represented in a coupled system.
- It is up to the impacts modeler to determine what the important ecological processes are, and what scales of land heterogeneity are important to capture them.

Can HRCM help us detect threshold changes?

- If statistical downscaling tells you that we're not sure about crossing a sensitivity threshold, whereas a high-resolution modeling says something different, this is an important contribution.
- Threshold events vs. extremes – sometimes the shift in the mean is important.
- It would beneficial if one could identify where runoff is more sensitive to convective as opposed to frontal systems, and identify need for HRCM output.

In what ways do HRCMs provide better information on drought evolution and feedback processes?

- There is added value from higher resolution to the coupled land surface and atmospheric processes, as it affects duration and intensity of extreme events
- Extremes that are regionally specific vary in regards to whether intensity or duration is more critical. Hence, resolving feedback processes at the local level is important.
- Large-scale phenomena may still be the main drivers of weather event duration, e.g., frontal rain and blocking.

How well do RCMs simulate changes in soil moisture or the interaction of atmosphere and soil moisture?

- Presumably not very well, but a promising place to start.

Usability

From "ecological modeling" and "climate change adaptation" perspectives, what needs could be met by high-resolution models?

- For ecological modelers, high-resolution modeling can provide a prompt to the ecological modelers to revisit and reconsider the climate-related predictor variables to include in their models with better advice on what data are available from the climate scientists.
- Insights related to non-linear and non-stationary changes in physical processes, including extremes, from the HRCMs can easily be incorporated into scenario planning.

What are some of the challenges related to uncertainty and bias in high-resolution models?

- Do not literally believe in the raw model output. Consider the output of an HRCM as one plausible representation that may or may not correspond to the actual outcome. This reinforces the need to use results from multiple models.
- Check to see if the same RCM (model, version & configuration) has been credibly tested against observations.

When and how can HRCMs provide increased usability relative to GCMs and statistical downscaling?

- HRCMs could provide physically consistent statistics of distribution and extremes of a climate feature, as well as physically consistent projections of variables for which there are insufficient observations to perform statistical downscaling.
- Well-documented and publically available gridded output in a usable format.

How sensitive does the ecological process have to be to require the use of an HRCM over statistical downscaling?

- Is it more important to have large range of possibilities or a few really accurate models?
- The sensitivity of ecological models to specific climate drivers needs to be included in any sort of decision tree for choosing models.
- For ecologists, it may be important to start with a sensitivity analysis. How much does a particular variable matter? If the model is not very sensitive (particularly to precipitation), perhaps statistical downscaling is adequate.

Which is more important in choosing a downscaling method: the type of ecological model, or the climate variables of interest?

- Presumably both, and there is a significant interaction between the two. In fact, one might need to revisit and slightly revise the ecological model based on new or improved variables from HRCM output.

What kinds of variables ecologists are interested in?

- Use of means is quite common in climate change impacts modeling.

- Type of model matters in terms of what data we need.
  (a) Mechanistic modeling: daily to sub-daily time step may be necessary
  (b) Statistical (correlative) modeling: monthly/seasonal variables
  (c) Scenario planning: Need to explore the various plausible responses (rates of change) in different relevant climate drivers.
- "What ecologists want" varies greatly depending on questions and the type of model used.
- For ecologists, finding information on what different climate models do well or poorly is difficult, even though that information may be out there.
- How much added value is there at a seasonal or annual time step from HRCMs?

What is the time horizon of planning, and does this impact data needs?

- Long-range vulnerability assessment vs. short-term management planning
- For short-range planning, it is perhaps more important to have more accurate methods of downscaling.

How can the modeler and user community work efficiently together to identify and satisfy needs for climate information?

- Never enough communications and collaboration (co-development and co-production); everybody is stretched so thin and effective communication takes time.
- How can boundary organizations – LCCs, RISAs, CSCs, Climate Hubs – better serve this need? The boundary organization and ecological modelers need to work with the climate modelers to present the divergent results as logical and meaningful information.